Building Energy Information Systems: State of the Technology and User Case Studies

Mary Ann Piette
Jessica Granderson
Girish Ghatikar
Phil Price
Lawrence Berkeley National Laboratory

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http://eis.lbl.gov/

Outline

- Study motivation and goals
- EIS Definition
- State of the technology findings
- Selected baseline methods
- User case studies
- Conclusions
- Future Work
- Discussion

EIS Study Motivation

- 2 closely related concepts
  - Realizing optimal energy performance requires more granular, timely data than utility bills
  - EIS can process data into actionable information, and link key efficiency stakeholders
- Advances in technology since 2003 study
- Current interest in energy displays, information dashboards, performance visibility, and role of feedback in reducing energy use
- Dozens of EIS are commercially available
  - Public domain info is often vague
  - Demo software may not be available
  - Salesmanship confounds differentiation

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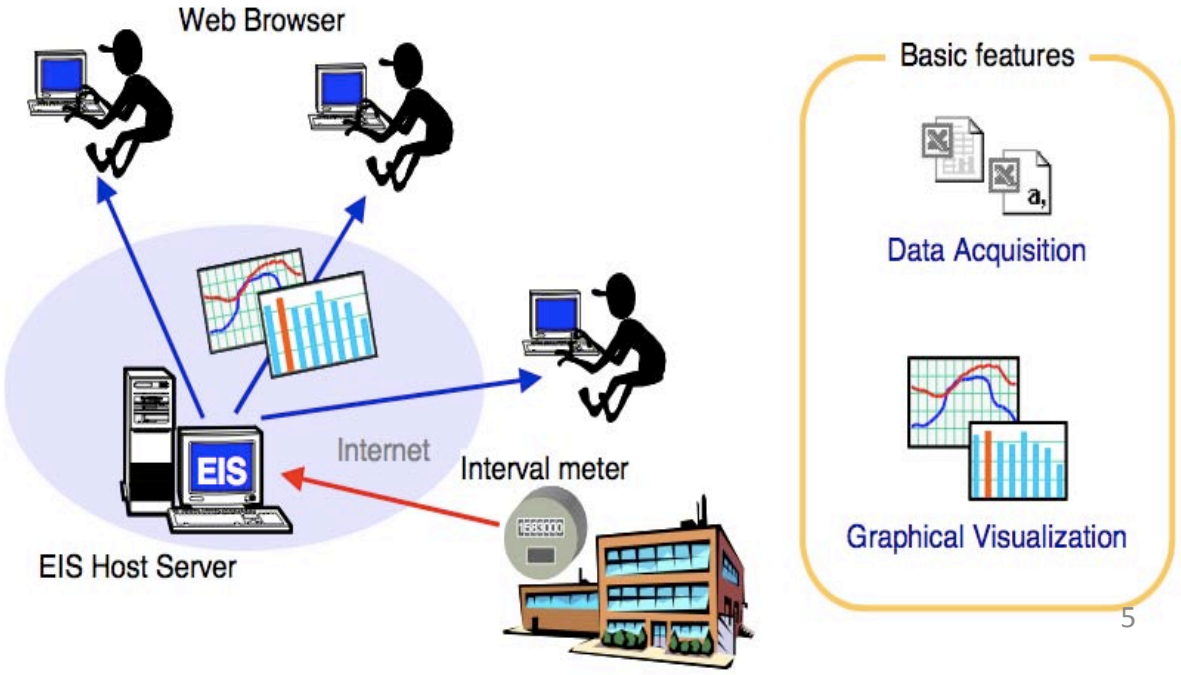
EIS Definition

- EIS comprise
  - Software, data acq. hardware, and communication systems
    - To collect, analyze and display building energy information



EIS Definition

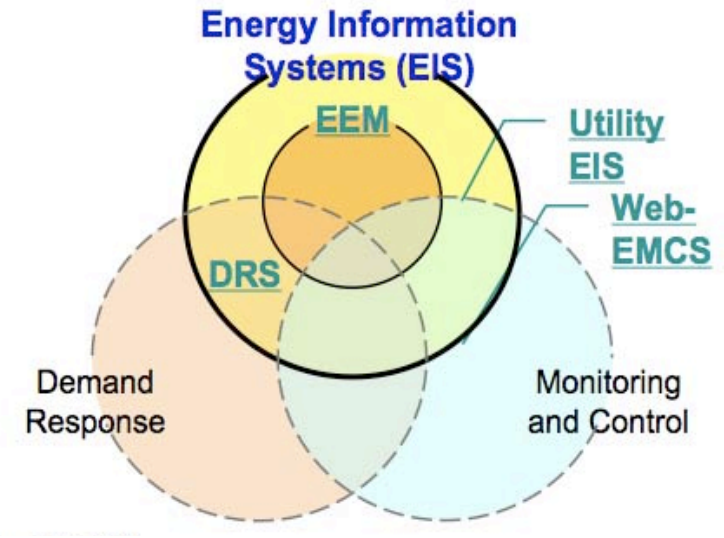
- EIS provide
  - Web-accessible hourly whole-building electric data
  - Graphical/visualization capabilities
  - Weather, energy price signals, and demand response (DR) information
  - Analyses such as baselining, benchmarking, energy costing, billing support …
- EIS are NOT
  - Most EMCS and equipment FDD
  - Energy information dashboards
  - Batch analysis tools
  - GHG footprint calculators
  - Environmental monitors

Summary of Key Findings

- State of the technology
  - Many EIS features have converged to a common set since 2003
  - Flexibility distinguishes many EIS
    - alteration of trending, plotting, and reporting parameters, and automated calculations
    - reconfiguration of reporting options
    - changes dynamic and on-the-fly or hard-coded
  - Robustness of energy analyses also distinguish EIS
  - Carbon tracking, DR capability, baselining and anomaly detection are new or more sophisticated since 2003
- Case Studies
  - Data quality is increasingly important with submetering, component/system monitoring, and non-electric energy sources
  - Resources and staffing were constraints in every case
  - Alternative models for effective, scalable EIS use need to be identified
  - Many EIS features are underused or not used
  - Technical basis of sophisticated features may not be understood by users, but can be used successfully
  - Common actions/saving relate to M&V, schedule verification, and inefficient operation
  - External software common with custom analyses and performance metrics

EIS State of the Technology

- Characterization framework of 8 categories, with 5-10 features each, applied to evaluate commercial EIS technologies, based on vendor interviews and demonstrations



- Vendors: Agilewaves, Apogee Interactive, Automated Energy, Automated Logic, Chevron Energy, Energy Connect, EnergyICT, EnerNOC, Envinta, FactoryIQ, Gridlogix, Interval Data Systems, Itron, Matrikon, NorthWrite, Novar, Noveda, Powerit Solutions, PowerLogic, Richards Zeta, SAIC, Small Energy Group, Stonewater Controls, Tridium, Ziphany

EIS State of the Technology

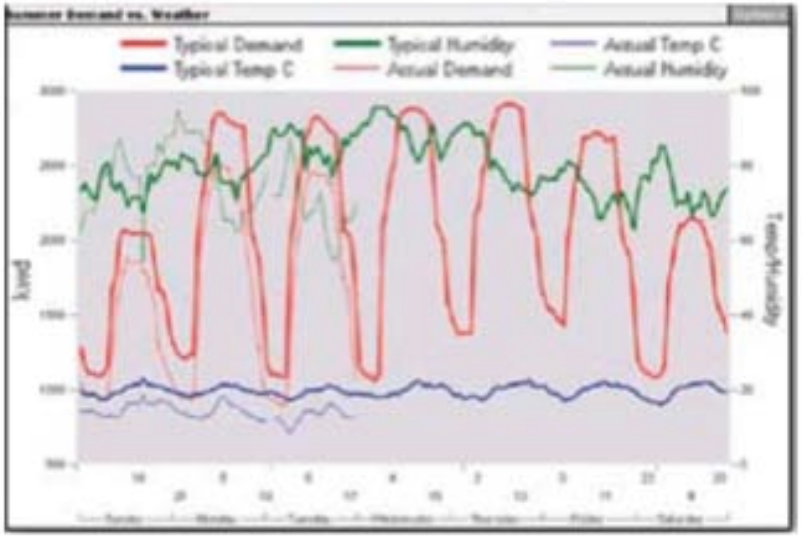
Disclaimer

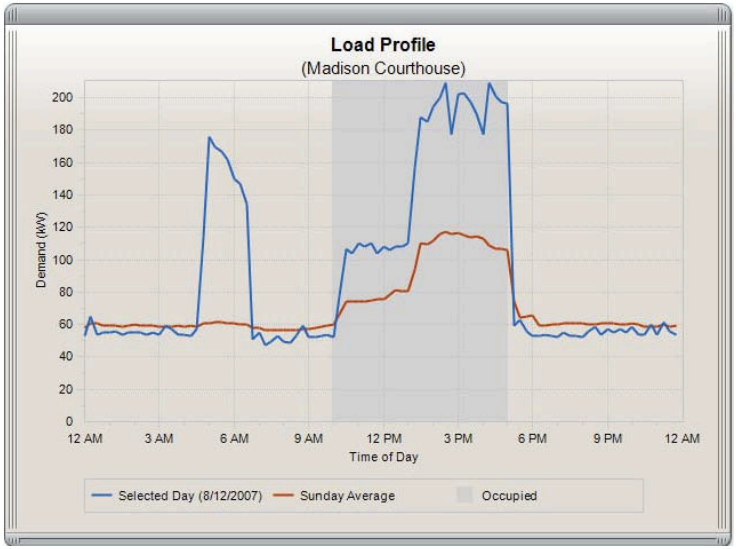
- All reported findings are based on vendor-supplied information at the time of the study
- Current capabilities are subject to change
- Readers are encouraged to confirm based on their specific needs
- The EIS that were selected for evaluation is representative, but not comprehensive, and inclusion in the study does not imply endorsement

EIS State of the Technology

Display and Visualization

- Features have converged to a near common set including load profiling, point overlay, aggregate totaling …
- X-Y scatter plotting remains an under-supported feature, offered in only half the EIS evaluated
- *Flexibility varies: display parameters dynamically altered ‘on-demand’ or statically defined in configurable options

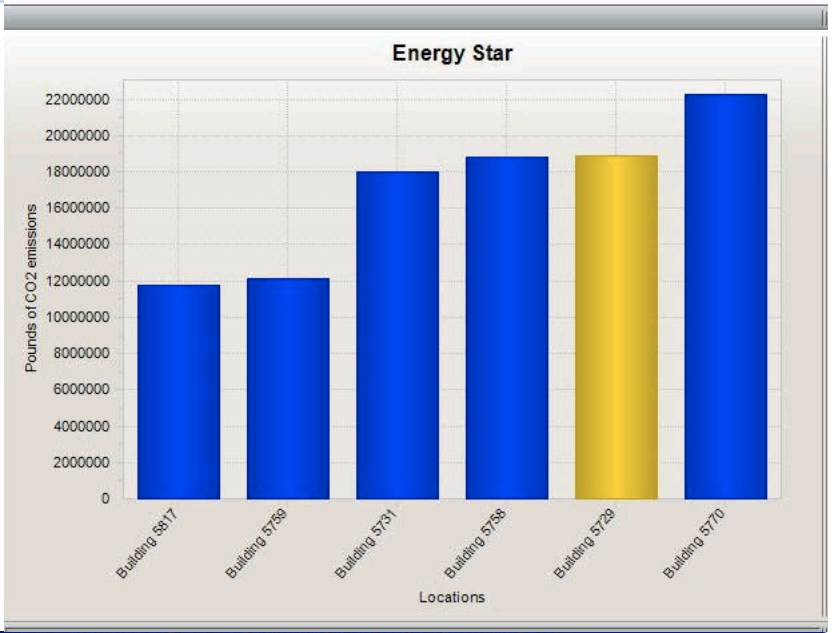




EIS State of the Technology

Energy Analysis

- 2/3 of the EIS support GHG analysis, almost half use regional generation or standards
- *Nearly all baseline, but weather normalization is rare
- Every EIS evaluated offers (or will) multi-site benchmarking, distinguished by
  - Composition of comparative cohort: w/in enterprise or vendor db, less commonly national
  - Display: static reports vs. dynamically accessible functions; shown as tables, plots, or charts



EIS State of the Technology

Financial and advanced analysis

- *Corrupted data - flagged or reported (VEE), cleansed or corrected, links to external software
- Anomaly detection via departures from normal consumption patterns
- FDD rare, some links to external software
- Tariff-based energy costing in ~half, DR tools tend to most robust
- Large majority support M&V or operational changes tracking (rigor varies)

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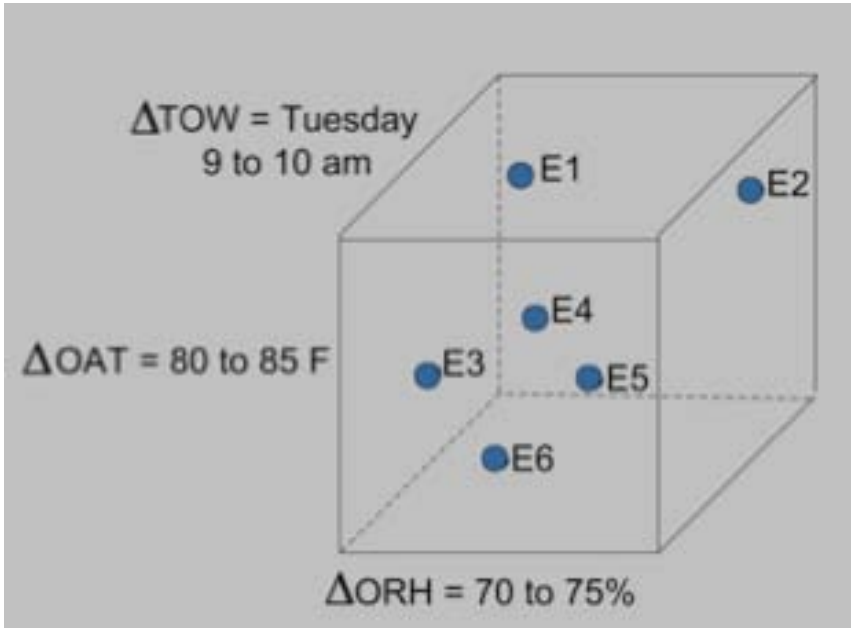
Selected Baseline Methods

- Baselines may be used for M&V or savings tracking, multi-site benchmarking, anomaly detection, and near-future load forecasting
- Sophistication varies, 3 more robust methods are reviewed
  - NorthWrite Energy Expert bin method
  - Energy ICT neural networks
  - Pulse energy weighted averaging

NorthWrite - Bin Methodology

- Data from each time period is placed in a “bin” that is defined by the outdoor air temperature, time of week, relative humidity, or other parameters.
- Predict the load for a time period to be the average of other loads in the same bin.
- May not work well for many explanatory variables or for unusual conditions.



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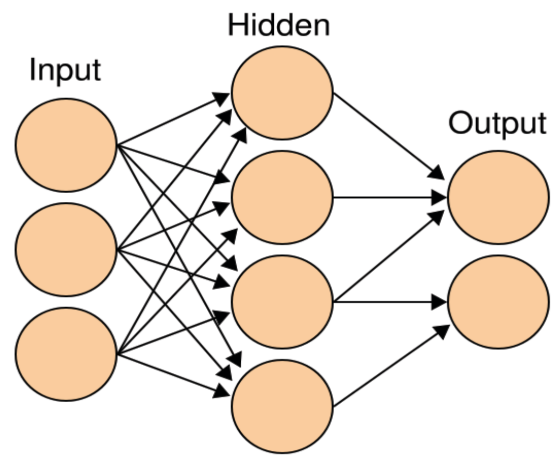
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Pulse Energy – Weighted Averaging

- Similar to bin method: identify data that come from time periods when conditions were similar to current conditions
- Predicted load is a weighted average of loads from those similar time periods
- Weighting depends on the degree of similarity
- Drawback: May not perform well for sets of conditions that have not been encountered before

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EIS User Case Studies

- Motivating Questions
  - How are EIS utilized in organizations that have them?
  - Which features have proved most useful in attaining energy savings?
  - What actions are taken based on the information provided via an EIS?
  - How much energy savings can be attributed to the use of an EIS?

EIS Case Studies

- Selection Criteria
  - Engaged EIS users with a role in commercial energy management
  - Aggressive energy savings

Case	Type, size (sf)	Controls	Performance Monitoring
UC Merced	Campus (800,000)	Automated Logic Corporation WebCTRL	Automated Logic Corporation WebCTRL Utility bills
UC Berkeley	Campus (15.9M)	Barrington Some ALC, Siemens	Obvius Utility bills
Sysco, Stockton CA Sygma site	Refrigerated/dry warehouse (95,000)	DOS-based refrigeration control	NorthWrite Energy WorkSite Utility bills
Wal-Mart	Retail/grocery (675M)	Novar Danfoss Emerson CPC	Energy ICT EIServer Utility bills

UC Merced

- Campus Features
  - 2005 opening, newest UC campus, 4 main buildings, central plant, housing/dining
- Energy Targets
  - Efficiency, measurement, prioritized in design stages
  - Goals: 20% better than benchmark, ramping to 35%, 50%

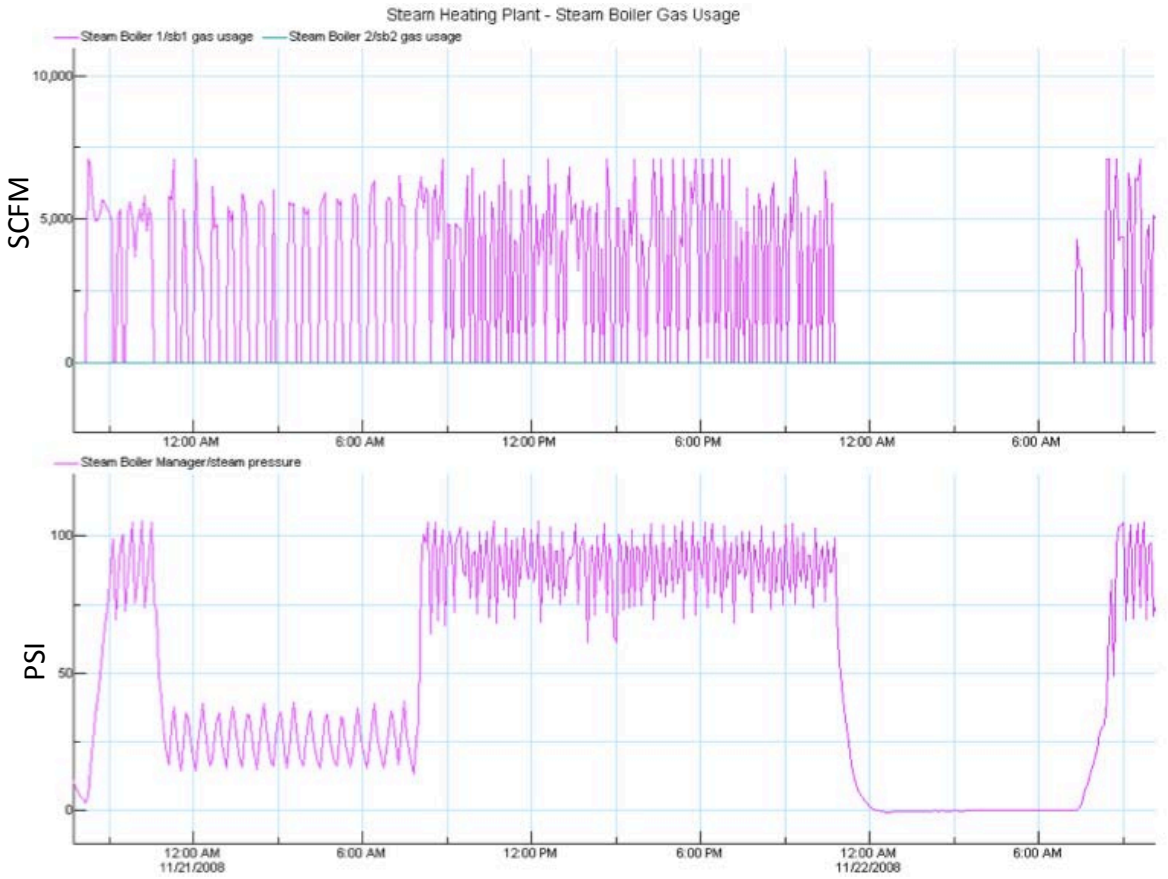
UC Merced

- Case illustrates
  - Challenges, successes in using a web-EMCS for intensive data collection, monitoring, energy Dx
  - the web-EMCS as enabling critical information links
  - realization of the campus as a living laboratory
- Automated Logic Web-CTRL
  - Selected for web connectivity, remote monitoring and control capabilities
  - EIS uses: energy performance tracking, assessment of utility recharges
  - EMCS uses: Building, equipment troubleshooting

UC Merced

- Data, information, action, savings
  - Steam plant trends to identify excessive overnight steam plant pressure
  - ~35% gas reduction

    $4500/mo est. savings
  - Gas trends and local steam measures to confirm steam plant efficiency



UC Merced

- 2007-2008 Energy Performance

	Campus Gas	Campus Electric	Campus Pk. Demand	Building Electric	Building Pk. Demand	Building Pk. Cooling
Improvement vs. benchmark	27%	34%	37-52%	42-45%	52-55%	15-36%

- Future data-centered energy management plans
  - Extend performance tracking to end uses, systems and components
  - Implement prototype advanced EIS-Dx tool (LBNL-UTRC)
- Challenges
  - EMCS (logic) and instruments not configured for EIS analyses
  - Intensive monitoring requires close attention wiring, system programming, network architecture and hardware selection

Wal-Mart

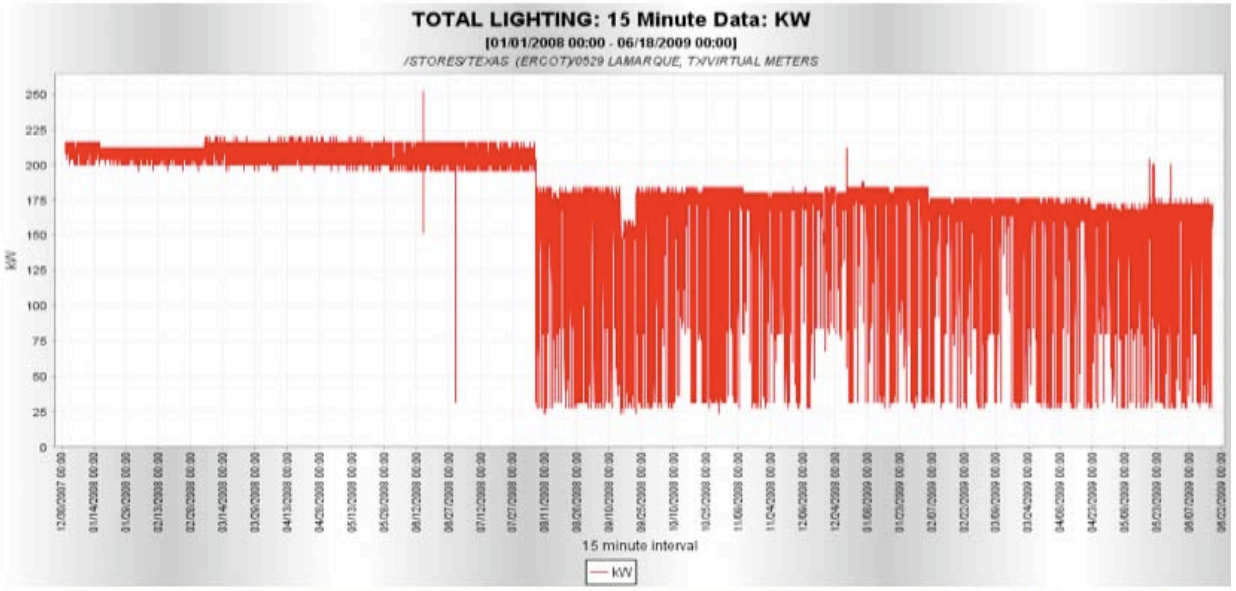
- 675M sf portfolio, EnergyICT EIS implemented in 2003
  - building and submetered electric: HVAC, ltg, refrig mains
  - subscription weather feed
  - some stores meter gas and water
- EIS philosophy: with $B utility expenses, 60-90dy billing cycles is insufficient.
  - Don't base retail decisions on 60dy sales data - energy considerations are just as critical
- Case illustrates:
  - Siloed use by specific groups or individuals for a few key purposes among various departments and teams in the enterprise.
  - regular operational analytics not yet widespread vertically or horizontally within the enterprise
  - Even more sophisticated EIS may not satisfy all organizational energy management needs

Wal-Mart

- Common EIS uses
  - M&V on ad-hoc basis by specific project teams: weather-normalized baseline forecasts compared to measured consumption
  - Power procurement and DR: forecasting and normalization features for week-ahead predictions (high accuracy, large expenditure decisions)
  - Individual stores: gauge the performance of new designs, particularly at 'High Efficiency' supercenters (1 report that EIS data used in VE simulation)
  - Portfolio tracking: benchmarking analyst exports data for custom model-based calculation of weather and sales normalized EUIs
    - 20 poorest performing sites IDd monthly, referred to op/maint
    - No use of EIS normalization for individual stores, rather direct comparison to similar climates

Wal-Mart

- EIS energy savings examples from M&V and benchmarking
- High store consumption: 225 kW static lighting load due to a failed dimming control module
- $35K avoided energy cost
- Identified failed VFD installation causing zero retrofit savings



Walmart
Save money. Live better.

Wal-Mart

EIS Challenges

- Mostly independent of the EIS technology (as reported)
- Submetering
  - Cost prohibits submetering to the extent desired by EIS champions
  - Consistent quality of contracted installations
- Integrating regular EIS use into standard daily activities,
  - particularly during the current economic downturn
  - Vision: staff-wide access through web-based executive reporting
  - 1 person benchmarks monthly vs. benchmarking *group* daily
- Custom models for portfolio benchmarking and High Efficiency performance tracking not easily accommodated in the EIS

Sysco

- Corporate energy efficiency program
  - Goal of 25% savings enterprise wide in 3 yrs (108 ctrs)
  - EIS modules developed in part for SYSCO needs
  - NorthWrite EIS + Cascade Energy Eng. services
    - EIS used on-site, and throughout corporate enterprise
    - 'Energy champion' responsible for performance at each site
  - Expert audits + EIS data → low/no-cost measures
  - Capital improvements over time
  - 28% savings achieved after 2.5 yrs (18% low/no)
- Case illustrates
  - enterprise-wide EIS use and information sharing
  - limited yet powerful on-site use of the EIS
  - use of EIS to ensure persistence in savings and accountability

Sysco – Stockton Sygma

- Site Features
  - Northern CA Stockton distribution center
  - 3 warehouse buildings – refrigerated and frozen space, dry goods, office (95,354 ft^3)
  - Old systems w/ virtually no control, dial-up DOS cmds for refrigeration systems, considering Einstein II
- Metering
  - 5 utility meters, 15-min pulses to central server via cellular
  - Op and shift changes seen in bldg meters (50% refrigeration, 20% lighting)
- Metrics
  - Unit-less 'efficiency factor' for each site
  - EF = f (wet bulb, kWh/dy, kWh, ft^3 frozen, ft^3 refrig)
  - Monthly ranking tables across portfolio regions (ex. in report)
  - Color coded tables to show up/down from prior month
  - kWh/ksf for the portfolio

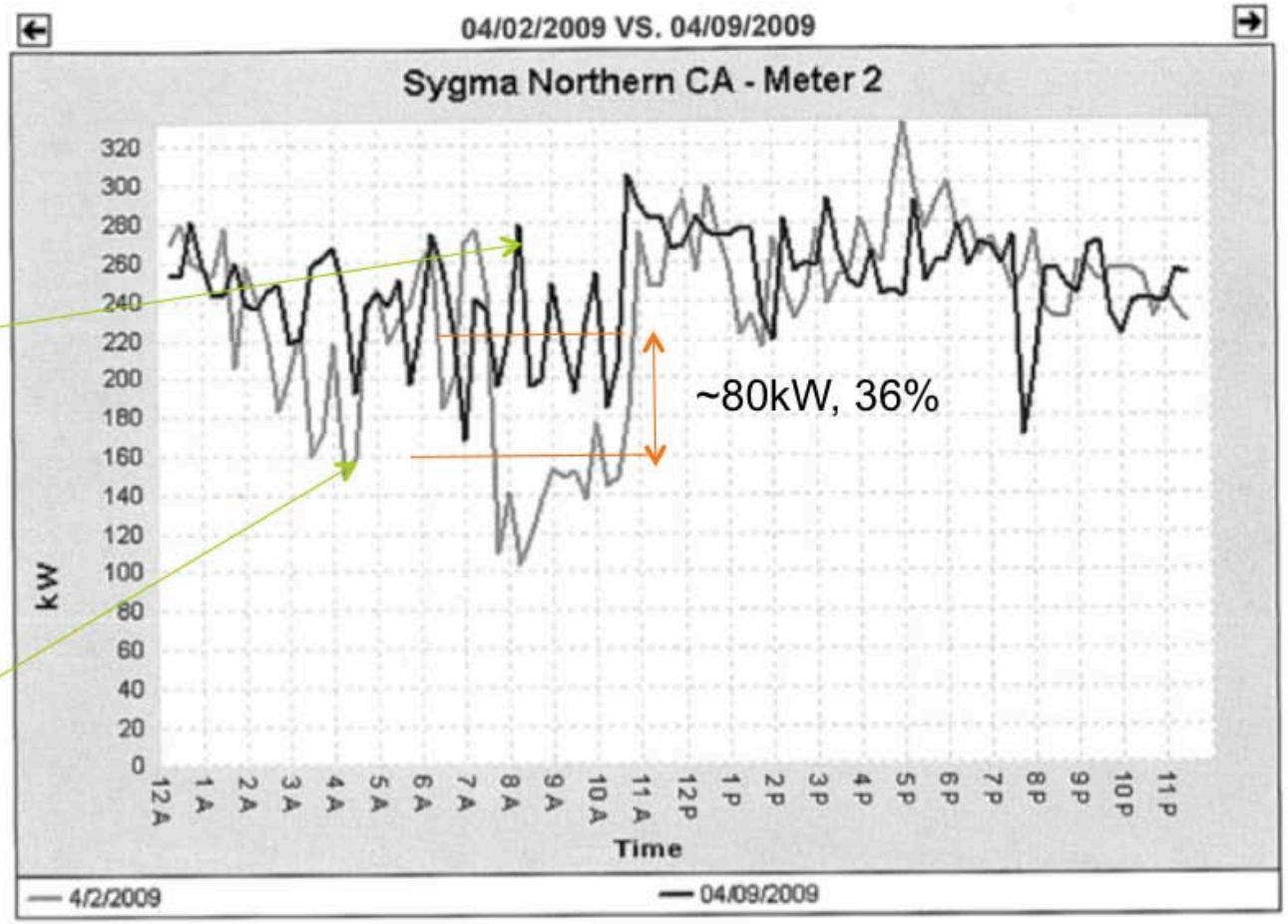
Sysco – Stockton Sygma

- Daily On-site EIS Use
  - Limited yet powerful use of EIS features
  - 95% of use – 1 meter (refrigeration), 1 view
    - Today/this week vs. last week, % change in use, temperature change
  - Daily, manual load reduction at 10 units
    - Systems will run 24/7 but don't have to
    - Frozen good can tolerate -5-10 degrees for periods
    - ~7AM setpoints raised to force compressors off
    - Temperatures monitored throughout AM
    - Setpoints lowered to normal ~11AM

Sysco – Stockton Sygma

Energy champ on vacation

Daily load reduction



Anchor Graph at Zero

04/09/2009: **5,873 kW**
04/02/2009: **5,567 kW**
Change: **5.5%**
04/09/2009 Average Ambient: **53°F**
04/02/2009 Average Ambient: **57°F**
Temp Change: **-4°F**

Sysco – Stockton Sygma

- Monthly EIS Use
  - Ensure loads drop as expected off-hours (lights)
  - NorthWrite reports to generate site rankings based on efficiency factor
    - Review meetings w/ project mgr and energy champions
    - Accountability mechanism
    - Culture of competition
  - Automatically generated utility reporting (lags)

General EIS use

- Successful initial stages, monthly accountability, culture of competition = no perceived need to use more powerful EIS features
- EIS most valued for supporting accountability and staff motivation for persistence in efficiency gains
- Are deeper savings possible?
  - use of the 'daily scorecard' to compare predicted to actual consumption
  - view month-long load profiles to identify historic trends
  - Use of forecasting to optimize the daily efficiency strategy?

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UC Berkeley

- No central EIS, contrasting case that shows
  - Challenges in the absence of a campus-wide performance monitoring system
  - Information needs at large ageing campus tasked with reducing its climate impact
- Large volume of energy and system performance data
  - disparate sources
  - used by different staff groups

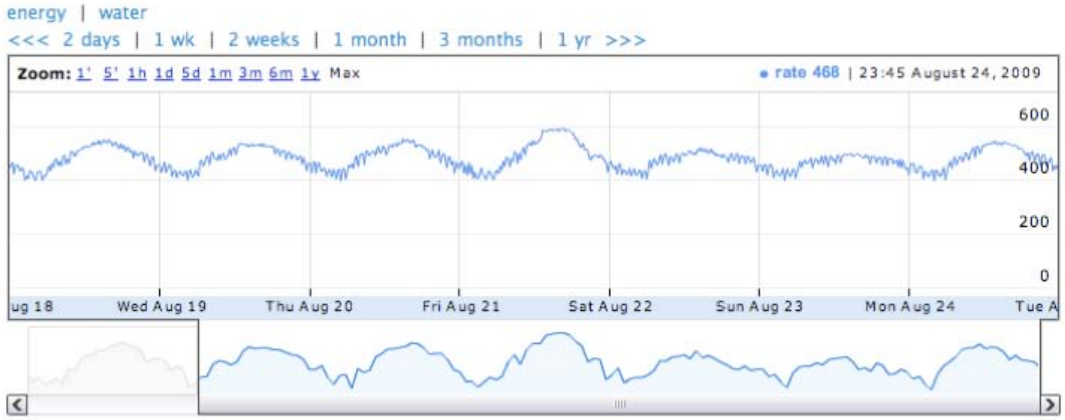
Data Sources	Number	Users, uses
Utility bills	Gas, electric	Invoicing, utilities staff
Whole-building electric meters, monthly manual reads	>100	Invoicing, utilities staff
Whole-building gas meters, monthly PGE bills	<100	Invoicing, utilities staff
Whole-building steam meters, monthly manual reads	<30	Invoicing, utilities staff
Web-accessible Obvius whole-building electric meters	20	Commissioning interventions
Prototype building performance monitoring website		
Barrington EMCS – control settings, states, equipment energy consumption	61 bldgs. 40K points	4-person EMCS staff

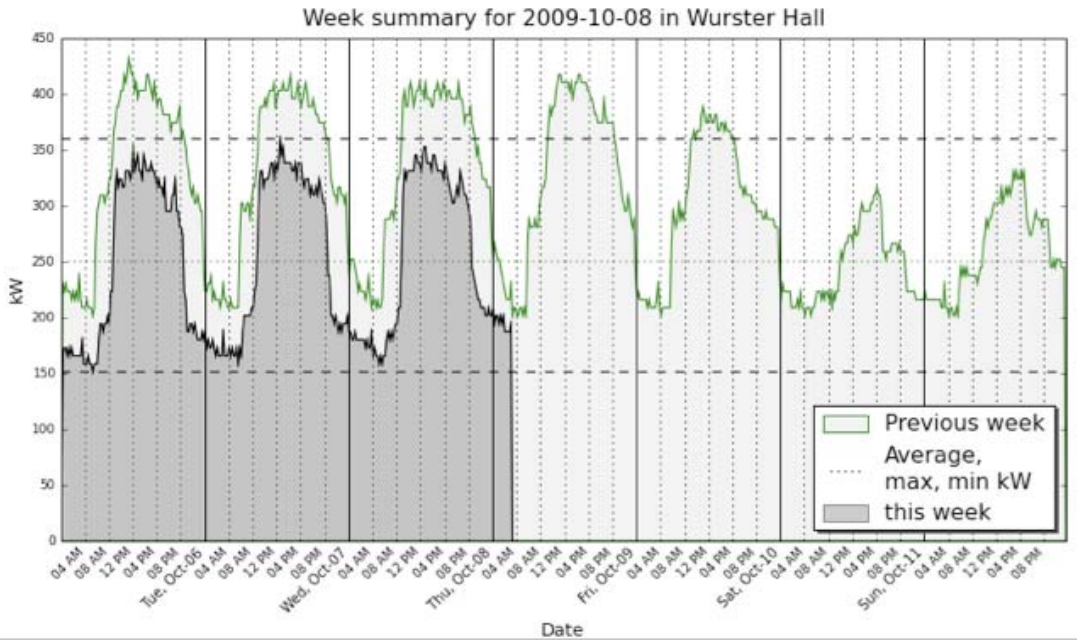
UC Berkeley

Data Uses

- Monitoring-based Cx – remote-access electric interval metering
  - ~30 buildings totaling 11M gsf
  - Obvius filed devices, daily upload of 15-min data to off-site warehouse
  - Obvius web app to visualize plot, export meter data
- The *Building Energy Dashboard*
  - Student funded research, pairs Obvius meter data with monthly utility data
  - Monthly representations of electricity, water, and steam
  - Real-time displays of meter data from Obvius devices
  - Targeted for occupants and students, useful to campus sustainability staff?

UCB *Building Energy Dashboard,* Prototype Screen Shots





'live data plot', zoom-able representation of most recent data

'detailed building plot', this week's consumption plotted against the previous week, with min, max, avg demand

student trials IDed excessive ventilation ops and over illumination

ventilation was reduced 6h, lighting retrofit conducted, resulting in a 30% reduction in total energy use

UC Berkeley

Energy Information Needs and Desires

- Prioritize building-level performance tracking, give feedback to building coordinators, EMCS and HVAC staff, and technicians
- More remote-access interval metering, with near-real time uploads
- Submetering
  - support improved decision making re technology, operations, and proposed use or space changes
- Access-controlled public data
  - Simplify satisfying data requests from researchers and special projects
- EIS not explicitly mentioned (nor familiar with), but implied in
  - challenge in processing the existing data
  - desire for remote-access permission-based meter data
  - Desire for higher density and granularity in electric metering

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Conclusions – EIS State of the Technology

- Visualization and analytical features are distinguished by flexibility
  - dynamic user-defined selections versus statically defined reporting, calculation, and plotting parameters
- Rigorous energy analyses - baselining, forecasting, anomaly detection- are not universal
- Vendors are reluctant to differentiate embedded default functionality vs. what *could be* performed
  - One EIS might have dedicated modules specifically for M&V
  - another might report that M&V is supported because of no-limit trend storage, aggregate totaling functions, and configurable arithmetic

Conclusions – EIS Case Studies

- EIS actions and energy savings concerned:
  - improperly scheduled loads
  - project M&V
  - inefficient or excessive operations

Site	Observation/Action	EIS Data Points	Energy impact
UC Merced	Excessive overnight gas use due to non-zero pressure at steam boilers	Steam plant pressure, gas	30% reduction in average daily gas use, $4,500/mo avoided costs
UC Merced	False peaks in observed chilled water demand at buildings, due to central plant operations	Building chilled water flow, supply and return temperature Central plant chilled water supply temperature	
Sysco	Lights left on after hours at Stockton Sygma	Building electricity	
Sysco	Multi-hour daily energy efficiency strategy at Stockton Sygma	Building electricity, control system setpoints and temperatures	35% demand reduction *Single observation
Sysco	Identification of low/no cost savings opportunities, e.g., retro-commissioning and refrigeration tune-ups	Warehouse electric meters	18% reduction in portfolio energy use 36% reduction in Stockton site energy
UC Berkeley	Excessive ventilation and over illumination identified, leading to lighting retrofit and ventilation schedule change	Whole-building electric meter	30% reduction in whole building energy use
UC Berkeley	Multi-week chiller lockout that prevented shut-down	Control system setpoints	
Wal-Mart	Static 225kW load at dimming control submeter	Submeter electricity	$35,000/yr avoided costs
Wal-Mart	Failed or disconnected VFDs used in retrofit programs		Avoided zero savings at program sites

Conclusions – EIS Case Studies

EIS Usability and Analysis

- Data quality can have a significant impact on EIS usability
  - UC Merced: failure to configure the instrumentation and web-EMCS for EIS analytics
  - UC Merced: large scale monitoring requires care in to wiring and hardware integration, system programming, and network communications
  - Wal-Mart, Sysco: embedded validation estimation error checking (VEE) routines, less submetering, focus on electric data
- Use of embedded analytical capabilities depends on performance metrics and benchmarking data
  - The more custom the calculations, the more likely that data will be exported for analysis in third party modeling or computational software.

Conclusions – EIS Case Studies

EIS Usability and Analysis

- Sophisticated baselining methods are not universally understood but are used to great success, in a 'black-box' manner
- EIS offer a wide range of features but actual use of these features can be very limited
  - users not always aware how to use features to generate energy-saving information
  - Sysco: partial use can result in powerful outcomes, but further savings may go undetected

Conclusions – EIS Case Studies

Organizational impacts and success factors

- The existence of data or software does not guarantee shared knowledge or actionable information
  - Sysco's enterprise-wide use encourages persistent savings, energy accountability, awareness
  - UC Merced's extensive use contributes to efficient operations, performance, living laboratory
  - Wal-Mart and UC Berkeley are both working to better leverage their data
- Resources and staffing were a significant constraint in every case studied

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Future Work

- The most useful features, potentially useful but underutilized features, and energy savings attributable to EIS
  - More extensive set of actions, savings, and consumption before and after EIS to quantify expected range of savings
  - Typical actions and associated features linked to a classification of standard EIS uses
    - M&V for retrofit support, continuous building-level anomaly detection, or GHG emissions reporting
    - building ownership models may have an impact
  - What are the best algorithms to detect waste?
    - Today's EIS anomaly detection is based on historic data
    - What if the building has never performed as intended
    - How can models improve diagnostics in tomorrow's EIS?

Future Work

Definitions and Scalability

- We define EIS broadly, stipulating whole-building energy analyses, graphical capabilities, web accessibility
  - many technologies included in the study are EMCS or DR tools that are less immediately thought of as EIS, but that *can be used* as an EIS
  - Should an industry standards group define a set of minimum criteria for a given technology to qualify as an EIS?
- The UCM case illustrated some of the challenges in using an EMCS as an EIS, indicating an outstanding research question
  - can an EMCS serve as a robust EIS, reliably adding whole-building energy analyses to control design intent?
- Scalability is a closely related, and may provide insights as to where to draw the line between EIS and related technologies
  - need to understand tradeoffs between diagnostics, trend volume and # of points monitored, and resulting burden on underlying hardware and communication networks
  - especially relevant as portfolios grow, or as user move to increased levels of submetering or subsystem monitoring and analysis

Future Work

Successful EIS Use and Deployment Models

- EIS are primarily considered the domain of in-house staff, w/ minimal services for install and configuration
- At alternate end of the spectrum, EIS may be intended for use by 3rd party service providers
- Prevalence of staffing constraints, Sysco case, and number of vendors that offer services, indicate the potential for other models
- *Cascade Energy Engineering is seeking opportunities for inclusion in utility energy efficiency programs
  - engineering expertise + services + on-site EIS = deep enterprise energy savings
- What are cost-effective, viable solutions for data-centered energy management in medium and small commercial

Future Work

- The outcomes this study provide the foundation for a broader set of case studies sponsored by the Department of Energy
- They will be pursued in collaboration with the New Buildings Institute, beginning in 2010
  - Focus on informing and supporting DOE National Accounts and Energy Alliances
  - Mix of commercial subsectors – large office, retail, hospital …

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